研究会報告

Stochastic Resonance in Electrical Circuit

Hideki YAMAZAKI[1], Atsushi MIYAGAWA[1], Osamu INOMOTO[2] and Shoichi KAI[2]
[1]Fukuoka Institute of Technology, Department of Electronics, Wajirohigasi Higashi-ku Fukuoka 811-02 Japan
[2]Kyushu University, Department of Applied Physics, Fukuoka 812-81 Japan

1. Introduction

A phenomenon that shows enhancement of input periodic signal intensity with increase in external input noise has been reported recently in bistable systems. This phenomenon has been called the stochastic resonance(SR) since signal-to-noise ratio(SNR) of an output periodic signal is rapidly improved within certain amplitude of noise like a well-known usual resonance.[1] In linear systems SNR at the output must equal to one at the input, and increase in the input noise results in a decrease in the output SNR. Therefore, SR is a nonlinear effect that is caused by cooperative effects of the noise and the periodic signal.

Theoretical studies for SR have been performed in several approaches. All of them are essentially based on the Kramers characteristic transition time between each potential well. Experimental studies have been done in various systems focus the main attention on observation of SR. All results show rapid improvement and then slow decrease of SNR as the input noise amplitude is increased. Results obtained by the experiments show good qualitative agreement with the theoretical ones. All theoretical studies have done for systems whose potential is double minimum. No attention has been payed to the potential profile not only in theories but also in experiments. Moreover, SR with two different periodic signals has not been studied. We describe these behaviors in the present paper.

2. Experimental

Experiments were performed using a circuit consisting of a tunnel diode (1S1763) with a resistor (R=505Ω). A bias voltage V_b for the tunnel diode changes the characteristics of the circuit. A potential of the system is calculated using a characteristic curve (I-V curve) and a load line which is determined by V_b and R (Fig.1). Sinusoidal signal [$V_s cos(2\pi f_s t)$] is applied simultaneously with a random Gaussian white noise(V_n). We measure the output voltage across the tunnel diode. SNR is the ratio of signal power at f_s to the background noise level at the sam frequency. Fig.2 shows V_b dependence

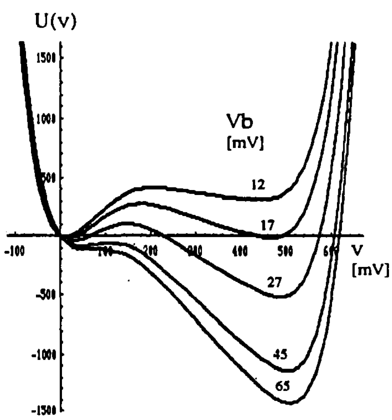


Fig.1

of SNR(f_s=1kHz, V_s=0.1V). The V_n dependence of SNR drastically changes. The intensity of SNR is largest when the mean residence times (Kramers time) for two potential wells become equal(V_b=27.3mV). The maximum SNR shifts to higher V_n as V_b is away from 27.3mV. This shift is resulted from deepening the potential well. Simultaneously, the maximum value of SNR becomes small and the resonance is less pronounced with increase in the difference. As shown by Gammaitoni et al. the increase of the correlation time of noise works as similar way.[3]

Fig. 3 shows V_n dependence of SNR when two different periodic signals f_{s1}(1kHz) and f_{s2}(2kHz) are applied as a potential modulation signal. SNRs of the fundamental and the higher harmonics show monotonic decrease with V_n when no resonance occurs(Fig. 3A). On the other hand, when SR occurs these higher harmonics are suppressed and the fundamental frequencies intensively remain(Fig. 3B). This result indicates that SR suppresses the mode coupling.

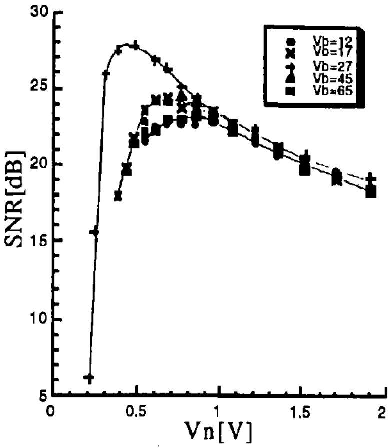
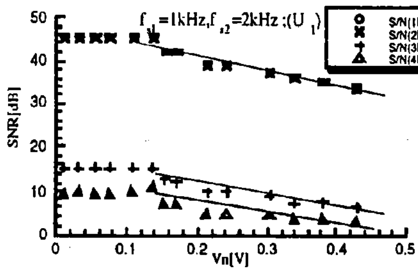
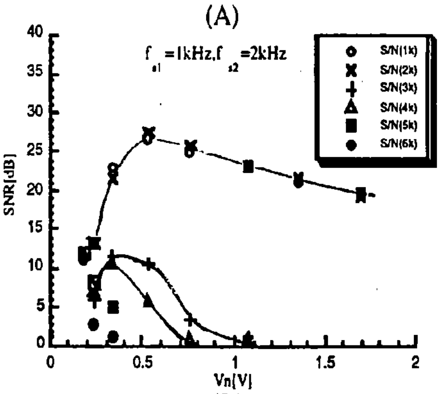


Fig. 2



(A)



(B)

Fig. 3

3. Summary

We studied experimentally on SR using electrical circuits. to investigate effects of the potential profile as well as the superposition of two different periodic signals as a modulation signal. Results are summarized as follows: (1) Asymmetric potential profile strongly influences the aspect of SNR. (2) SR suppresses the mode coupling which produces harmonics. As no theoretical work has been done in this direction, the detail will be reported in the near future.

This work is partially supported by the Grant in Aid for Scientific Research from the Ministry of Education, Science and Culture in Japan.

References

1. R. Benzi, G. Paris, A. Sutera and A. Vulpiani, Tellus **34**, 10 (1982).
2. L. Gammaitoni, E. Menichella-Saetta, S. Santucci, F. Marchesoni and C. Presilla, Phys. Rev. A **40**, 2114 (1989).